On the Perignathic Girdle of the Echinoidea. By Prof. P. Martin Duncan, M.B. Lond., F.R.S., F.L.S., &c.

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(Plates XXX. & XXXI.)

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I. Introduction and Terminology.

The first definite notice of the nature and use of the perignathic girdle with which I am acquainted, was written by that careful anatomist the late Dr. Sharpey, F.R.S., in the 'Cyclopædia of Anatomy and Physiology.' In the article "Echinodermata" (1839, vol. ii. pp. 33 & 36) he gives views of the parts; but although he describes the muscles of the jaws and their attachments and origins, and explains the nature of the "auricles" to a certain extent, he disposes very briefly of the ridges or plates which are between the auricles in the Echinus he anatomized. He may be quoted as follows:—"At its lower edge the shell sends inwards a process in form of an arch over each pair of the ambulacral columns." The figure (10 *a*, p. 33) shows the arches and also the intermediate structure. On page 36 it is stated:—"The muscles and ligaments belonging to the dental apparatus partly pass between its different pieces and partly connect it with the border of the shell. It will be recollected that the border of the shell forms five processes which rise in the form of arches into its cavity round the lower aperture."—"Two muscles come from every arch."—"Other ten muscles arise in pairs from the border of the shell in the interval between the arches."

It is evident that Sharpey gave the information which was current at that time and that the "auricles" were well known,

but that the interauricular parts were confounded with the border of the shell. The connection of the auricles of *Echinus* with the ambulacra was both drawn and described.

J. Müller (Bau d. Echinodermen, Berlin Akad. 1854) gives a most perfect figure of a *Cidaris* and describes the "auricles" from that genus only. He figures the ambulacrum with the projecting knobs seen within the test on either side of the median line, and terms them vertebral processes. Nothing can be clearer than the fact so well illustrated by the great anatomist, that these "auricles" have no connection with the ambulacra and that the ascending processes in *Cidaris* are interradial.

It is evident that the "auricles" of *Echinus* noticed by Sharpey are not homologous with the auricles of *Cidaris* as described by Müller.

Lovén, in his wonderful 'Études,' p. 29, in treating of *Cidaris*, states:—"Là les auricules n'offrent pas de résistance. Fixées par leurs bases exclusivement aux plaques interradiaires des deux côtés de l'ambulacre," &c.

Lovén gave moreover the following very important description of the "auricles" of other genera:—"L'existence d'un appareil masticatoire puissant et très-compliqué, pourvu de cinq pièces d'appui, dites auricules, dont les bases élargies sont fixées par soudure à la face interne des plaques péristomiennes et subpéristomiennes du test, *soit ambulacrales*, *soit interradiales*, &c." The meaning of this refers to the difference in the position of processes in *Cidaris* and the true auricles of all the other Gnathostomes (Clypeastroids excluded) with which Lovén was cognizant.

A. Agassiz, in the 'Revision of the Echini,' 1872–74, p. 689, states:—"In the Desmosticha, on the other hand, the jaws are placed entirely within the line of the auricles, from which they are supported by a very complicated set of muscular bands, extending in pairs from the sides of the auricles, from their base and from the intervening spaces, to different points of the pyramid and of the braces."

On the next page he writes:—"The auricles are interambulacral processes: they are developed from the test itself, and do not belong to the dental system as stated by Lovén, while the teeth and jaws are developed independently as isolated pieces in young Echini.

"In the Cidaridæ the processes of the adjoining interambu-

lacral auricles are closely connected, and appear to be more intimately connected than in Glyphostomata, where the inter-ambulacral processes on each side of the intervening ambulacral space form an arch which may or may not be closed, and of which the extremity is more or less closely soldered together."

A. Agassiz gives excellent figures of the auricles and pays much attention to their condition in the Clypeastroids.

It is perfectly clear that there is a great diversity of opinion between Lovén and Agassiz.

T. H. Stewart gave a description of the jaws and of their muscles and their attachments to the body of the test. The description was accompanied by a drawing, and, as might be expected, they are models of clearness and correctness.

The form which Stewart investigated (Proc. Zool. Soc. 1861, p. 53) was not one of the Cidaridæ, and the origin of muscles from "auricles" and intermediate interradial ridges clearly proves that the arrangement is not the same in the Cidaridæ (see J. Müller's figure) and in the other regular Echinoidea with jaws.

Charles Stewart examined the structures of *Dorocidaris papillata* and gave an excellent description of the internal branchiæ, of the jaw-chamber, and of the compasses and their use. In illustrating his paper ("On certain Organs of the Cidaridæ," Trans. Linn. Soc. vol. i., Second Series, Zool. pt. xxii. p. 569, pl. lxx., 1877) the author gave an excellent figure of the top of the jaws, the compasses and their ligaments, the branchiæ, and the part of the test between the ambulacra to which some muscles are attached.

There are also two admirable drawings of the ambulacra, and Müller's vertebral processes are well shown; and their spinulose analogues, which Mr. Stewart noticed curving over the ambulacral vessels, are represented *.

Terminology.—The term "Auricle," taken from fancied resemblance to little ears of the arched processes of the structures which give attachment to the jaw-muscles, is one which should lapse.

* Wyville Thomson held that the structures I call the "perignathic girdle" were distinct from the test. In his essay in the Phil. Trans. vol. 164. pt. ii. p. 731, he states that in the Echinothuridæ "the ring of calcareous elements forming the auriculæ and their uniting ridges appears to be entirely distinct, merely forming adhesions with the ambulacral and interradial elements."

The shape of the so-called auricles of the Cidaridæ differs from that of the other Echinoidea, and the construction of the part in Discoidea differs also. No ear is like unto any one of these structures, and they have nothing whatever to do with hearing.

Very frequently the arch of the processes is incomplete, and then there is no possible similarity between them and the outlines of an ear.

It is proposed to discontinue the term auricle. No definite name has been given to the ridge-like plate which connects the so-called auricles together, and which really is of as much importance as the processes, which arch more or less over the ambulacra.

The whole of the structures of the test which give attachment to the muscles of the jaws require a name, and that of the *perignathic girdle* seems to have some useful qualities.

The girdle is, when fully developed, continuous, and consists of arched processes and intermediate ridges. The discontinuity may be slight or very decided.

The Cidaridæ differ entirely in the arrangement of their jaw-muscles, so far as attachment to the test itself is concerned, from the other dentate regular Echinoidea, and the solid so-called "auricles" are parts of the interradia. There are no ambulacral processes for the retractor muscles, and therefore the girdle is discontinuous.

In Discoidea there is a continuous girdle without arches, although the homologues of the processes exist *.

The terms *ambulacral process* and that of *ambulacral arch* should replace the terms "auricle" and "auricular arch." In speaking of the jaws and their accessories for muscular attachment, the word *process* or *arch* will suffice; and the term *interradial ridge* may be employed, with or without the word interradial, to distinguish the ridge-like structure which unites the ambulacral arches and gives attachment to the protractores and radiales.

II. The Perignathic Girdle of the Cidaridæ.

A small but well-developed specimen of *Dorocidaris papillata*, Leske, presented the aspect of the discontinuous perignathic

* The anatomy of the test of *Discoidea cylindrica* will form the subject of a future communication to this Society.

girdle which was so well drawn by J. Müller, and figured, with the aid of photography, by A. Agassiz in the 'Revision.'

The processes do not exist, and the tall, stout, notched, and sideway-slanting interradial ridges form the whole of the discontinuous girdle. An interradial ridge is high and broad, and notched on its upper edge at the median line, so as to give the appearance of being formed by two halves placed side by side, and a vertical suture passes down from the notch to the peristomial margin *.

The upper edge of each half of the ridge is convex and thin, and is produced sideways so as to partly overhang an ambulacrum, (Plate XXX. figs. 1 & 2). The outer, that is the circumferential, surface of the ridge is slightly convex from side to side and from above downwards; and internally the surface is slightly concave above and rather tumid below. The upper edge overhangs the concave surface at the upper part of the ridge on either side of the median line, and this surface is the point of attachment of muscles. In the midst of this concave surface, and about halfway down the ridge, there is a small depression on either side of the median line and midway between the outer side of the ridge and the median line. The sides of the ridge are curved, concavity towards the ambulacra, and the suture between the ambulacral plates and the ridge on either side is nearly vertical at the peristomial edge (fig. 1).

The general direction of the ridges is upwards and slightly outwards, so that they are not vertical, and the lower part of each ridge projects more towards the axis of the animal than the upper and free part (fig. 3). The lower part has tubercles in relation to it actinally, and the characteristic ununited plates of the Family are attached to the lower and inner part of the ridge where it merges into the peristome, and the union is membranous. Circumferentially the ridge slopes rather sharply at first from above downwards, and then more gradually so as to merge into the upper surface of the coronal plates near the peristome. The ridge is thin above, and stout lower down where it joins the general surface of the plates just mentioned (figs. 2 & 3).

Seen from without, the outer (circumferential) surface of the ridge has the median suture of the interradium coming in a

* Benzene was used when requisite to render the sutures distinct.

zigzag close to its starting line from the ordinary level, and it is very perceptible (with benzene, and sometimes without that excellent distinguisher of sutures) that the median suture passes up the median line of the ridge, but not in a right line, there being a slight curving (fig. 2).

The sides of the ridge on either side of its median suture correspond with zones "*a*" and "*b*" of the interradium, and it appears at first sight as if the side of the ridge corresponding with zone "*b*," for instance, was composed of a long plate the circumferential angle of which extended beyond the ridge and assisted to form part of the interradium, and that in the ridge the zone "*a*" was composed of the whole of a plate*.

But it is evident that in zone "*b*" the apparently long plate is not a whole one, for there is a delicate suture which passes from the convexity of the curve of the median suture, as seen from within the test, and has an oblique upwards and sideways course. This suture unites a small terminal plate (figs. 2 & 4). There is no such plate in the other zone (*a*).

Both of these zones are limited by an ambulacro-interradial suture.

The direction of the sutural union of the terminal plate of zone "*b*" with the plate immediately external or circumferential to it is from the outer surface of the ridge inwards and downwards and it terminates actinally. Hence this small plate comes to the under or actinal surface of the test, and it carries there the smallest of the interradial tubercles at the peristome. The plate external to the small one has its sutural union also oblique and reaching the actinal surface, and it is recognized there as the second plate of the zone "*b*" which carries the first large tubercle (fig. 3). On the other hand, the plate of zone "*a*" which forms the whole of one side of the ridge reaches actinally and carries there the first largest tubercle of the interradium. The ridges of the girdle in *Cidaris* are thus composed of an upward growth and thickening of the first and second interradial plates in one zone, and of the first plate in the other zone, and there is no additional structure. There are no structures in *Cidaris* which resemble or are homologous to the processes of the girdle of the other families of the regular Echinoidea. J. Müller and C. Stewart have described and drawn certain nodular projections, which are almost spines in places, on the ambulacral plates; their position is on either side

* Interradium 5 (the odd posterior) is chosen for illustration.

of the median suture of the ambulacrum, and the vertebral processes as they were termed by Müller, as well as the spines, are elevations of the interporiferous parts of the plates. Some of the projections unite on the side of the median line and others nearly arch over the vessels and nerves in that situation. No muscular fibres are attached to the projecting nodules.

The peristomial edge of the first ambulacral plates of *Cidaris* is low, and a pair of pores will be seen, if care is taken, on either side of the median sutural line (fig. 1).

These pairs are continuous with those of the first pairs seen on the actinal surface of the solid test; and it is evident, from their position on the ambulacral edge within the peristomial membrane, that no muscular attachments can come in on that inner edge.

In the Cidaridæ all the muscles which protrude and retract the jaws arise from or are attached to the interradial ridges.

In *Cidaris*, owing to the particular character of the peristomial membrane which is covered with separate plates, the jaws cannot appear so clearly outside the test and beyond the membrane as in *Echinus* for instance. The retractores of *Cidaris*, which open the jaws inferiorly, are not so much required as they are in *Echinus*, which extends and widely separates and gapes the ends of its jaws in an astonishing manner. Hence the processes of the girdle are all important in *Echinus* and can be done without in *Cidaris*, the ridges being sufficient.

Goniocidaris geranioides, Link.—The perignathic girdle resembles that of *Cidaris* (*Dorocidaris*): the ridges are well developed; the "vertebral processes" of the interporiferous zones of the ambulacra are small.

The ambulacra are narrow at the peristome, and no part of them contributes to the girdle. The first two ambulacral plates are rather high, in comparison with those of *Dorocidaris*, at the peristomial edge, and the upper surface is often notched at the median line. A pair of pores is seen on the inner surface of each of the first ambulacral plates, and these openings are close to the upper edge of the plates; they correspond with the first pairs of pores visible on the actinal surface of the test. The peristomial membrane and its plates are attached to this inner surface of the ambulacral plates, below the position of the pores, and consequently there are no muscular origins or attachments on the plates.

A line of suture separates the interradia from the ambulacra

at the peristome, and it can be traced readily on the free inner surface of the test at the peristome (fig. 8).

Each interradium has a tall, forked ridge occupying the whole width of the area; there is a vertical median line denoting that the ridge is composed of at least two plates, one from each zone, and the flanks of the ridge are produced sideways above, so as to overhang the ambulacra more or less. The direction of the ridges is strictly obliquely upwards and outwards, and they are rather tumid low down and more or less concave near their upper edge.

It is evident that a ridge is composed of an upward growth of the first coronal plates (one plate in zone *a* and two in zone *b*), and its base corresponds with the first pair of interradial tubercles of one zone, and of the largest tubercle near the peristome of the other zone. There are no perforations on the flanks of the interradial ridges of the girdle, and, as will be seen further on, the ridges, like those of *Dorocidaris*, are not homologous to the processes of other Echinoidea.

The comparatively high inner edge of the first ambulacral plates is very suggestive in relation to the corresponding part in Discoidea; but it does not appear that the height is due in *Goniocidaris* to anything else than the usual elevation which separates the ambulacral plates one from the other, in vertical succession. The plates are tall and have a transverse elevation on their upper surface.

Phyllacanthus imperialis, Lmk.—There are two good specimens of this form in the British Museum, and one shows a most interesting difference from the usual type of the perignathic girdle in the Cidaridæ. In one specimen the free edge of the ridges is very deeply notched and the ridge is low at the median line and high at the sides, which overhang the ambulacra considerably and with a double curve. In the other the median notch is deep, and the sides of some ridges are so produced over the ambulacra that they either absolutely unite with the opposite ridges or very nearly do so. (Figs. 5 & 6.)

In one instance the union over an ambulacrum is so perfect that the idea of a perignathic process cannot but arise in the thoughts of the observer. There would be room in this arch for the usual muscular attachments of a process (fig. 7), as in the Echinidæ.

III. The Temnopleuridæ.

It was thought best to take a species of the Temnopleuridæ as an example of the characteristic perignathic girdle of the Glyphostomata of the Regular Echinoidea, on account of the readiness with which the sutures of the plates separate.

Salmacis bicolor, Agass.—The large specimen of this species which was examined in the first instance has a large and fully developed perignathic girdle, which is continuous, and consists of five ridges and five arches, each of these last being made up of two processes united above (fig. 9). The whole girdle is stout, tall, and slopes obliquely upwards and outwards.

The ridges of the girdle are rather tall, and have a sharp upper free edge, with a projection at the spot above the median line, and there is a slight concave or downward bend of the edge on either side of the median process. The upper edge bends inwards very slightly, and immediately below it, on the inner or peristomial surface of the ridge, is a slight hollowing on both sides of an imaginary median line, for the attachment of a muscle; and below these hollows is a decided transverse concavity, which is placed immediately above the inward projection of the base of the ridge, which corresponds to the bases of the first two tubercles seen on the actinal surface. This transverse hollowing is not very broad, for there is a more or less vertical groove on either side of the same surface of the ridge, which is pronounced below on either side of the basal projection, and which becomes shallow towards the top of the ridge, where it is lost. These lateral grooves (β) are continuous with the "cuts" for the branchiæ, and they nearly entirely belong to the ridge; but a small part, and that forming the side of a groove towards the ambulacra, is on a girdle-process. The line of suture which passes obliquely from above downwards (s), and which indicates the union of the ridge and a perignathic process, marks the outer part of the branchial groove. This suture commences above at the free edge of the ridge, where the upward slope of a neighbouring process begins, and it has a direction obliquely downwards and sideways, so that the base of a ridge is broader than its free upper edge (fig. 9).

The ridges are thin from without inwards at their tops, and they become thicker towards the base, and this corresponds at

the actinal surface of the test with the first tubercles of the interradial area (fig. 10).

Although the sutures of this species are so readily separable, and the plates can be isolated so easily, still no separation will take place down the median line of a ridge (figs. 11 & 12). On the other hand, it is noticed that one of the zones (*b*) of the interradium has a large plate coming to the base of the ridge, and separated from the plate which forms the bulk of it by a transverse line of suture, whilst the other zone (*a*) has a small plate which forms only a small part of the ridge in advance of the plate of zone *b*. The succession of large interradial plates, and the presence of a very low plate in one zone, and of the great plate of the ridge, which has no median or other suture, are very constant peculiarities in this and other specimens (fig. 11). The direction of the inner or peristomial sutures of the plates at the base of the ridge is from above, inwards and downwards obliquely; and the relation of the large plates to their tubercles on the actinal surface of the test can be easily seen, but that is not the case with the small plate, for usually it is too high up (fig. 12), nevertheless it may have a vestige of a primitive tubercle. The great plate (zone *a*) which forms all the rest of the ridge is evidently placed over the first large tubercle of its zone of the interradium. Both plates in zone *b* have tubercles actinally.

In a smaller specimen of the same species the ridges were easily separated from the adjacent processes at the lines of suture, and the separated faces of the ridge showed lines of sockets and intermediate lines of depression and furrowing * (fig. 12). These corresponded with knobs and ridges on the separated face of the process; and when both surfaces were studied, it became evident that a third and upper plate entered into the composition of the ridge (figs. 12 & 13).

Were it not for the presence of the relics of a suture on the sides of the ridge there would be no reason why the undivided plate of a ridge should not be named plate 1, and be made common to both zones, as in so many edentulous Echinoidea. Then the plates in zone *a* would be Nos. 2 & 3, &c., and in zone *b*, 2 & 3 (fig. 11). But this cannot be correct. Plates 2 cannot be thus numbered, for there are *at least* three plates. (See further on.)

The examination of the ridges proves that they are composed

* See Duncan, Journ. Linn. Soc., Zool. vol. xvi. p. 353.

of interradial plates, and that there has been union of the terminal, or rather primary, plates so as to obliterate the median and other sutures. The ridges are united by separable sutures with the processes, are grooved for the branchiæ, and are marked by muscular impressions. Two sets of muscles are attached on each side of the inner face of a ridge—the thread-like radiales, probably ligamentous, and the large and broad protractores.

Variation.—The size of the median projection on the upper free edge varies, and is often absent in young specimens.

The processes of the girdle enclose an ovoid and rather pointed opening over the peristomial part of each ambulacrum, and the tall, broad processes, upwardly curved at the top, contrast with the comparatively small openings. The processes of each ambulacrum are joined by a vertical suture in the median line above, are broad from side to side and thin from before backwards, and slightly bent inwards superiorly, although the general direction of the processes is that of the whole girdle, namely upwards and slightly towards the circumference of the test. The slope of the side margins of the processes to reach the tops of the ridges is abrupt, and the suture which unites them with the ridges is long vertically and rather narrow from within outwards. When this suture is separated, the articulating surface of the process being exposed, it is found to present opposite characters to those of the corresponding part of the ridge. There are numerous knobs (fig. 13) placed in a space close to the base, and above they are limited by a set of lines of knobs and elevations more or less oblique in direction. Above are some more knobs and linear ridges, and quite at the top of the surface there are other knobs. The impression given is the same as that noticed in describing the corresponding surface of the ridge, except that in the process the markings are all convexities, and in the ridge they are all receptive concavities. It is evident that the relics of the borders of three plates exist.

At the peristome the edge of an ambulacrum, which is bounded by the origin of the process on either side, is low and is marked by the ambulacral median suture, and by grooves and pores on either side of it, for the passage of structures which come from the inside of the test to reach the bases of the actinal pedicels (figs. 9, 11, 14). The pores on either side of the median line are placed on the ascending base of a process and on the peristomial face. On looking at the process at its back and ambulacral side, at least

two pairs of pores and as many incomplete plates can be seen to form the foundation and much of the ascending part of each process (figs. 11 & 14).

These plates have distinct sutural lines (under benzene) between them and at the median line ; but their outer or ambulacro-interradial sutures are not seen, and the plates therefore merge into the general mass of the process on their side remote from the median line (fig. 14). The direction of the plates is very oblique.

Next to these plates, towards the radial end of the ambulacrum, are broader ones (Nos. 5 and 6, fig. 14), which have their interradial sutures visible and in contact with the more or less vertical suture of the ridge and process, as it merges into the common ambulacro-interradial suture. These do not add to the bulk of the process.

The union of the plates at the base of the processes is too decided to admit of separation, and it appears, therefore, that the processes are the result of the combined growth of the whole of the poriferous parts and some portions of the interporiferous zones of the first four or five ambulacral plates.

The possibility of the upper part of the processes being a structure superadded to the ambulacral plates arises from the fact that fracture occurs very readily between the middle of the process and the top, and along an oblique line from one side downwards and inwards towards the median line of the ambulacrum. No other line of ready fracture occurs, and the surface of the fracture is plain and smooth. Nevertheless the use of benzene does not distinguish any line of suture or of union at the part.

Temnopleurus toreumaticus, Agass.—Small specimens were examined in the first instance, and their perignathic girdle appears to be smaller comparatively than that of *Salmacis*, the processes are not so broad, are more delicate, and the small opening is oval and not sharply angular in outline superiorly, as is the case in *Salmacis*.

The ridges are not high in relation to the height of the processes, and they are broad. The upper edge of a ridge is thin and bent, with a bold downward curve, and there is no projection. The grooves in continuation with the cuts for the branchiæ are not very pronounced, but the projection inwards of the usual peristomial swelling immediately over the tubercles is decided.

Hence there is a hollow above this swelling, and between it and the upper edge. There are markings for the insertion of protractor muscles on either side of the median line. The sutures between the sides of a ridge and the corresponding processes are slightly oblique and nearly vertical; they commence on the upward slope of the ridge, and the direction of the sutural line is sideways and away from the median line of the ridge and downwards. The result is to make the breadth of the base of the ridge broader than the upper edge.

There is no median suture to be traced in the ridge by means of benzene, and when the structure is examined from within the test (circumferentially) it appears that the arrangement of the coronal plates in the zones of an interradium near to and in the ridge is very simple. In one zone a coronal plate with distinct sutures forms part of the ordinary plane surface of the test close to the rising up of the ridge, and the rest of the plate contributes to a small portion of the ridge. It is therefore a plate with a curved upper surface, and it is thick from within the test actinally, and carries a tubercle on the actinal surface. In the other zone a coronal plate comes to the edge of the rising part of the ridge, and enters very slightly indeed into the ridge itself. It is followed by a low but broad plate, which forms a part of the ridge, and reaches to about the same height in it as the single coronal plate of the opposite zone.

The whole of the ridge above these plates is composed of a single plate without the trace of a suture in it, median or otherwise, and it is sutured to the plates just noticed inferiorly, and with a process on either side. The arrangement is as in *Salmacis*.

The processes unite above in a broad arch, and they are thin there and have a line of vertical suture. They are stout at their bases, and there is a decided projection passing down the internal surface (that looking towards the jaws), which slopes obliquely towards the ambulacral median line separating the first pair of pores from the second. The side of the base of a process towards the ambulacral median line has four sets of pores on it. The first pair has its pores close and oblique; and a little care shows that the pair do not belong to one plate, but that the pore nearest the peristomial edge is in relation with a groove in the edge, and that they are the apertures of the first plate. The other pore of the pair is in relation with the groove on the edge nearer the median line than the other, and the groove and pore

are the apertures of the second plate. (See the fig. 14 of *Salmacis*.) The pair of pores next to this last on the flank of the process are close, and the outer or aboral pore is a long way off the suture between the ridge and the process. The pair belongs to a third plate, and its sutures are visible, under the effects of benzene, between it and the plates, nearer and further from the peristome; but no suture can be traced towards the division between the process and the ridge, and therefore the part of the plate remote from the ambulacral median line merges into the mass of the process, as in *Salmacis*. The next pair of pores are on the flank of the process which trends circumferentially, and the pores are more distant than the others; they belong to a plate which is not separable from the process. The succeeding pair of pores are wide apart, and they belong to a compound plate, which has all the sutural lines visible under benzene, and therefore this plate does not form a part of the foundation of the process. Four plates at least enter into the composition of the base and upward-stretching parts of the process.

The suture between the ridge and a process, when seen from within the test, passes almost in a right line to reach the flat upper surface of the actinal part of the test, just beyond the slope of the ridge, and then it clearly becomes continuous with the ambulacro-interradial suture.

It must be understood that the position of the pairs of pores on the flank of a process is very oblique, and that the direction of what remains of their plates is upwards and sideways from the direction of the median suture of the ambulacrum. This uptilting enables the plates to add to the height and thickness of a process.

Microcyphus zigzag, Agass.—This species has a thick test, and the peristomial edge bends in, and although it is said not to have "cuts," they are as evident as are the small and narrow grooves continuous with them on the inner side of the perignathic ridge.

The perignathic girdle is high, and the processes are rather slender; they are united by suture superiorly, and the space they enclose is somewhat triangular. The base of a process and the part formed by the first four or five ambulacral plates resembles that of the Temnopleuridæ already noticed.

The ridges are tall and comparatively narrow, and the free upper edge of each is curved downwards, or there may be a projection on the edge at the median line (fig. 15). The

suture between one side of a ridge and a process is tall, nearly vertical, slants but slightly, and it traverses the outer edge of the branchial groove. The peristomial swelling over the actinal tubercles is usually tall, and not united in one mass, but more or less separated along the median line as well as transversely. Immediately under the somewhat overhanging upper edge of a ridge are two distinct depressions, one on either side of the median line, and the base of each depression is curved downwards, and there is a blunt projection between them at the median line. The height of the ridges is remarkable.

The direction of the girdle is as in the other forms, and is upwards and slightly outwards, that is towards the circumference.

Amblypneustes ovum, Agass.—The perignathic girdle is stout, high, and oblique.

The ridges are broadest below, and the whole of the groove on either side of one comes within its area, so that the suture between the ridge and the process is oblique from the upward slope of the ridge downwards and towards the median line of the ambulacrum.

The free edge of the ridges is curved, and there is a median projection.

The processes slant gradually from the upper edge of the ridge and are rather narrow, they join above by median suture; and each is expanded laterally there. The space included is tall, triangular, and rounded slightly at the angles.

It is quite evident that the Temnopleuridæ have the perignathic girdle made after a different plan to the Cidaridæ, and it is proved that the processes which enclose the opening over the peristomial part of the ambulacra are parts of the ambulacra. The processes are made up at their bases and to a certain height by combined and deformed and, to a certain extent, displaced ambulacral plates, and especially of their poriferous areas. A process is united to the ridge on the interradial area by suture. A ridge consists of interradial plates and there is a single plate which forms the greater part of the ridge at and below its free upper edge. There is no separation of the interradial ridge of the perignathic girdle into two parts by a median suture as in *Cidaris*.

There are some points about the origin and structure of the perignathic girdle which are not quite clearly made out in the Temnopleuridæ, and it is therefore necessary to consider the girdle in the Echinidæ, and in some of the other Triplechinidæ and Polypores also.

IV. The Echinidæ.

Echinus norvegicus, Düb. et Kor.—The perignathic girdle is very delicate and incomplete in the young forms, but becomes strong and well developed in adults. The processes of adults are high, and rather broad from side to side above the margin of the upper edge of the ridges. They are united as a rule along the median line above, and the included space is of moderate size; it is broad below and more or less angular above, and the sides of the space are curved inferiorly and slant to the upper angle. The base of a process slants in the direction of the median line of an ambulacrum; and it is limited, on the interradial side, by a line of suture, which slopes from the curved edge, where the ridge merges above into the process, to the actinal surface of the test, just on the ambulacral side of the slight cut and groove for the branchiæ. The direction is in a curve downwards and towards the median line of the ambulacrum. The result is to increase the width of the part of the peristome which is in relation with the ridge, and to diminish the width of the base of a process. The upper part of a process has a well-marked upper edge with depressions below it for muscular attachments, and the area of these is also increased by the expansion of the process on either side above. The ascending part (fig. 17) is obscurely triangular in transverse outline when fractured across, and there is a projecting line which passes along the peristomial side, that is the true inner face of the process, so as to cross the base obliquely. This line separates the pores and grooves of the first ambulacral plates, which are at the very edge of the peristome, from the three plates which are seen at the back part of the base of a process (fig. 17). Taking the basal part of the first process that comes to hand, it will be noticed that the peristomial edge is marked by three grooves (fig. 16)—the one nearest the median line of the ambulacrum being small and without a corresponding pore, whilst the others have each a pore corresponding with them, that of the groove furthest from the median line being high up on the base, the other pore being lower down.

On the back part of a process three minute pores may be seen, forming a curve, the third pore being further from the ambulacral median line than the others. These pores, which are oval with a minute angularity below, are the outer pores of so many plates, the inner pores of which are larger and much nearer the

ambulacral median line. The sutures between the plates to which the pairs belong are seen with benzene, but their ambulacro-interradial sutures do not exist; for the plates, the direction of which is very oblique from above and towards the median line of the ambulacrum, merge into the mass of the process at their part remote from the median line. Thus in this species, as in the Temnopleurids, the base of the process is certainly composed of parts of the poriferous zone of ambulacral plates increased in height and crowded.

It is necessary to admit that the ambulacral plates which are visible at the peristomial part of the process—that is, the first, second, and third plates, and those three others seen on the process behind it, that is plates 4, 5, 6 of the ambulacrum—may enter into the composition of the base, and of more or less of the upper part of the process in one zone *a*, in a specimen of nearly adult dimensions. In the opposite process (fig. 17) two plates are in front and three behind the process, and none have ambulacro-interradial sutures; they compose the process of zone *b*.

The perignathic ridges of this species are low, and they are curved downwards at the upper free and narrow edges. The width of a ridge at its edge from suture to suture is less than the width of the peristomial part of the corresponding interradium. On the peristomial face of a ridge there is a swelling at and on either side of the median line and just above the actinal edge. On either side of this there is a groove which is continuous with a branchial cut, and above the swollen part there is a concavity surmounted by long markings for the attachment of the protractor muscles (fig. 16).

On examining the other side of a ridge, or from the circumference inwards, it is to be noticed that there is no median suture near the edge, and that under benzene certain plates become very distinct. A single plate, which is relatively much less developed in height than in the Temnopleuridæ, forms the whole edge of a ridge, and it varies in height according to age. Following this plate, in one zone (*a*), there is a low plate and a higher one, and all the low plate and a small part of the next enter into the formation of the ridge's base. On the other zone a large plate succeeds the single one, and part of it rises in the base. (Figs. 24 and 18: the transverse line *a'* is the level of the rise of the base. Provisionally the plates of fig. 24 are numbered as if they were in direct and normal succession; the single plate is 1, and it is followed by 2,

3, and 4 in the zones. But the correct numbering must follow on the examination of some of the other groups, for, as suggested in *Salmacis*, the single plate was really not such a structure originally.)

A large form, closely allied to the species just considered, has tall and broad processes, which are expanded laterally on each side of the vertical median suture above. The opening they enclose is a tall triangle in shape with the angles rounded. The ridge is very low, much curved downwards at the free edge, and marked on each side of the bulge of the base of the tubercle-bearing plates at the peristome by the groove leading to the branchial cuts. The bulge is not simple however, and it is made up of two sides with a median depression. The sutures between the processes and the ridges are very distinct.

Young Form.—The growth of the perignathic processes was attempted to be understood by the examination of a number of small specimens of *E. norvegicus*, varying from 5 to 8 mm. in diameter. In the smallest form the plates of the test were few, and those of the ambulacra were distinct and wide apart. The processes were the merest nodules, were widely separated, short, and with a narrow and almost circular base (fig. 21); they were united by suture to the ridges, and the line of union was distinct even without benzene, so that it was perfectly evident that the stunted growths were not on interradia but on ambulacra (fig. 23). Every process was a portion of the first ambulacral plate, on either side of the median line at the peristome, and it was evident that the position was on the outer poriferous portion of the plate for the first pair. The first pair of pores were pushed towards the median line by the base of the process, and the aboral pore of the pair perforated the base of the process (fig. 17).

The position of the base of the process was then on the poriferous zone close to the edge of the peristome, and close to the ambulacro-interradial suture. It is proved, therefore, that the process is not homologous with the so-called "vertebral processes" of Müller, which are growths of interporiferous areas, and there can no longer be a doubt that the processes are ambulacral growths and not interradial. Even at this early age the processes had feeble muscular slips. The ridges were very low and insignificant, and their edge was composed of an entire plate as in adults, and it was a miniature of the ridge already described and drawn in fig. 24. Slightly larger specimens showed the processes to be taller

and still disunited (fig. 20) ; and the suture between the processes and the ridges could be separated, and then it was seen that there were at least two plates forming a ridge (fig. 22) : nothing could be seen with any reagents which would prove that the single plate was divided in the youngest and smallest forms. The largest of the specimens showed that the processes unite above very soon, and that they grow upwards with the general growth of the test (fig. 19).

Echinus esculentus, Linn.—There is an excellent preparation of a large test of this species in the British Museum, and the girdle is well shown. The processes are large, broad, and rounded above, and the position of their vertical suture, which was high, cannot be seen even with benzene, for perfect union has occurred. The space included by the arch of the processes is large and the ridges are well developed, and they have the usual number of plates.

Psammechinus miliaris.—If the characters of the structures of the perignathic girdle of *Echinus* be remembered, it will only be necessary to treat of those of the corresponding parts of this species briefly. The processes of the girdle are rather tall, and are rather narrow superiorly, where there is normally a slight bending forward of the upper edge, and a corresponding convexity of the outer or circumferential part of the summit. Usually the vertical height of the suture which unites the processes above is small (fig. 25) ; and it sometimes happens that they are not attached by a suture, and there is not a completion of the arch over the included space. This disconnection is not by any means uncommon. The included space is ovoid or obscurely triangular in outline, or it may be decidedly triangular. When there is no arch, the processes are less aslant (fig. 26), and may approach the upright in position. Often the tops of the processes only just touch. The sutures between the processes and the perignathic ridges are very distinct, and often so without benzene (figs. 25 & 26) ; and each commences at the upward slope of the process from the free edge of the ridge, and passes downwards with a curve which has its convexity towards the base of the process. The suture just comes within the edge of the branchial groove on each side of the ridge.

The peristomial margin within these sutures, which belongs to the ambulacra, is marked by the notches and is perforated by the corresponding pores of the first series of ambulacral plates ;

and some of these are to the median line of, or in the inner and peristomial part of, the base of a process (fig. 26). Usually there are the relics of four grooves with their pores (some often absent) on one side of the peristomial edge and on the base of a process, and of three grooves and their pores, more or less complete, in the base of the other process of the arch; that is, ambulacral plates 1–4 and 1–3 in the respective zones. On looking at a process from behind, much crowding of plates and pairs of pores is seen, and at least three pairs of pores, representing as many plates, are placed obliquely at the base and at the inner flank of the process; they (fig. 30) correspond in their position to the pairs of *Echinus*. Hence in *Psammechinus* the base and much of a process is made up of three plates visible from behind, which are the plates 4, 5, and 6, or in the opposite process plates 5, 6, and 7. Besides these, there are the plates seen in front or at the peristomial edge, numbering 1–3 or 1–4. A process in *Psammechinus* may therefore be composed of the oblique and hypertrophied poriferous parts of seven plates.

There is the same disposition to fracture in the processes above the spot of the uppermost externally visible pores; but no sutures can be seen with even the aid of benzene. That there are canals passing out of sight in processes and communicating with pores is evident; for on fracturing a process moderately high up a pair of canal-ends became visible (fig. 31). (This may be also seen in *Strongylocentrotus*.)

The ridges are moderately high and are broadest inferiorly; the upper edge is concave, and there may be swellings on it close to the median line. The branchial grooves and other features of the peristomial face of the ridge are as in *Echinus*. The construction of a ridge is very much the same as in *Echinus* (figs. 27, 28, 29).

V. The Echinometradæ and the Diadematidæ.

Strongylocentrotus lividus, Lmk., sp.—The perignathic girdle of this species is slender; the processes are moderately tall, slender, united above, without much lateral expansion there, and they have narrow and tall openings. There is much crowding of the ambulacral plates at the base of a process; and three or four pairs of pores may be seen from behind to be on the base, back, and inner flank of the process. There are as many plates in front. The ambulacro-interradial sutures of all these

plates are wanting, and the plates merge into the mass of the process. The ridges are low and broad, and are well-marked by the attachment-lines of muscles; and the branchial grooves are well developed.

The interesting and important points in this species and genus are *that the ridge is composed of more than one plate at its free edge, and that two or even three interradial plates may enter into its composition there* (figs. 32, 33, and 34). In fig. 32 it will be observed that the plate 1 of zone *b* has pushed aside plate 1 of zone *a*; and this can be well understood if the nature and position of the first plates of both zones in an *Echinometra* (fig. 35) are studied. When there are three plates at the edge (fig. 33), it will be noticed that the growth of plate 2, zone *a*, has pushed aside the first plate of its zone. Plate 1 of zone *b* is in its normal position.

It will be observed that in zone *a* there are two plates following the first, and that one is low and the other is large. This is the succession as seen in *Echinus* and the Temnopleurids. Again, in the zone *b* the plates, both of which are large, are numbered 3 and 4; and these are the homologues of the two large plates which succeed to the single plate in *Echinus* &c. Plate 2 of this zone has no representative in *Echinus*, unless it is admitted that it is united with the first plates of both zones to form the single large edge-plate in this last-mentioned genus. This must, I think, be admitted. The ridge of *Cidaris* is composed of two plates in one zone, and one in the other; but there is no fusion as in *Echinus*.

As might be expected, there is much crowding of the pairs of pores and of their plates in the base and for some distance up the processes. There are at least three pairs of pores and as many plates to be seen at the back and inner flank of the processes, and all traces of the ambulacro-interradial sutures are, as is usual in all processes, lost. But the next plate in succession has its outer suture forming a part of the ambulacro-interradial (fig. 38). There are the usual plates seen at the peristomial side. Now if the ridge be separated at its junction with the process and ambulacrum, a moderately high face of union is seen (fig. 39). This face is marked by almost vertical lines and with some which are slanting, and each depressed line is the corner between two ambulacral plates; and the rounded projections on the face, and which are bounded in front and

behind by the lines just mentioned, are the interradial projections of the ambulacral plates. Plates 4 and 5 will be seen to have rounded and tall plate-ends which come up to the ambulacral surface just below the position of the figures.

But no other plates come up to the line, and they are all at the base and within the mass of the process. The line marked *x* is of great interest, and in some specimens it is visible without reagents on the peristomial face of the test (fig. 40). In this figure the suture, for such is the inner part of the line, passes towards the median line from the suture between the process and the ridge. In fig. 39 the line of suture *x* passes to the peristome, and it marks the upper surface of the poriferous zone whence the process started.

Echinometra lucunter, Leske, sp.—The most striking part of the perignathic girdle of the species of *Echinometra* is the cap, or top projection of the combined processes (fig. 36). This cap is moderately large in the species now under consideration; and it seems like a growth upon the tops of the processes, which covers each one and joins it with its fellow. But the caps are not new growths, nor are they produced by any additional structures; for benzene fails to detect any divisional line between them and the top and posterior part of the processes. The one structure merges into the other, and the caps are growths of the ordinary tissue of the processes. The direction of the processes is upwards and backwards, so that their tops are much more distant from the polar axis of the test than the peristome. The caps seem to diminish this distance in *E. lucunter*, and they evidently give additional points of attachment to the retractor muscles. The arrangement of the pores and their plates on and in the flank of a process close to its base are very much as in *Strongylocentrotus*; and the suture between the process and the ridge fails to be in contact with at least three ambulacral plates at the back of the process.

The ridges of the girdle are long and low; and they are not made after the type of those of the Echinidæ or Temnopleuridæ, but after that of the allied genus *Strongylocentrotus*.

Two conditions prevail, and in one (fig. 35) what may be called the normal condition is seen; that is, there are two plates at the edge of the ridge above, and one is the first plate of zone *a*, and the other is the first plate of zone *b*, and they are symmetrical.

The median line is short, for the plates are low. In zone *a*

plate 1 is followed by plates 2 and 3; and in zone *b* there is the same succession, but the plates of zone *b* are the largest.

In the other condition (fig. 34) there is almost a complete resemblance to one of the combinations seen in *Strongylocentrotus*, where one of the first plates is very small and much of its normal position is occupied by the second plate of the same zone. Were the plates of this combination which come to the edge of the ridge taller and all combined into one, there would be the counterpart of the single edge-plate of the Echinidæ and Temnopleuridæ; in other words, the large plate 1 of zone *b* and the small plate 1 of the opposite zone combined with plate 2 of zone *a* would form a single plate on the plan of *Echinus*.

In concluding this notice of the girdle of the Echinometradæ, it is necessary to remind naturalists that the most extraordinary processes of *Echinometra subangularis* have a tall rectangular cap. It looks very much like an addition to the processes; and indeed it cannot but be a subsequent development induced by the large retractor muscles which this species requires.

The Diadematidæ. *Diadema setosum*, Gray.—The great width of the ridges, their small height, the slender sloping and connected processes, and the extension of the ambulacral area inwards towards the peristome and beyond the bases of the processes characterize this genus. There is nothing to notice in the processes of unusual nature; but they are readily separated from the ridges; and indeed the specimens sometimes fall to pieces, and show stirrup-shaped pieces which are the arches of processes and the ambulacral bases from which they sprang.

The ridges are interesting; and there is always a low median suture to be distinguished with benzene; but the arrangement of the plates at the free upper edge is very varied.

The diversity is due to the crowding of the plates during the growth of the ridges, and to the consequent absorption and alteration of shape of some of the implicated plates. In one specimen (fig. 41) the plate 1 of zone *b* occupies all its half of the edge; but the corresponding plate of the other zone is small, and so the plate 2 comes in at that half also. These plates are succeeded in the normal manner by others of different dimensions in the two zones. In another specimen (fig. 42) the plate 2 of zone *b* has pushed up and inwards the first plate, which occupies only a small space at the edge near the median line and suture; whilst in zone *a* the plate 2 is very close to the edge, being removed only by a very low plate 1.

In the third specimen (fig. 43) the second plates of both zones come to the edge, and the first plates of both zones are crowded towards the median line and are narrow and tall. This is a complete departure from the type of *Cidaris* and *Echinus*. In fact, the very unsymmetrical method of junction of the plates 1 and 2 in fig. 43 seems to indicate that the first plates might be lost altogether (fig. 49). The sutures between the ridges and processes are easily separated owing to their lamellary condition; and it can be seen, on the face of the junction of the ridge and the process, that there are three plates in the ridge of that side which come to the interradial sutural face (figs. 44 and 47). The part of the ridge which is produced towards the peristome is seen in fig. 45.

Echinothrix Desori, Peters.—This species has exceedingly broad and very low ridges; and in most instances there is a median projection on a ridge at the free curved edge. The ridges are formed by three plates in each zone, instead of one in addition to the usual single and double plate of the different zones (fig. 48). At the edge there is a triangular and small plate with its suture at the median line, slightly departing from the vertical; and the other suture is between this plate (1), zone *a*, and the succeeding low but broad plate 2. But this last plate is oblique, and reaches from the free edge near the process to the median suture. Then comes plate 3, also oblique, and being the usual large plate of the zone. In the other zone, *b* (fig. 38), the first plate occupies the whole of the upper edge of the ridge on its side; and plate 2 is the usual low plate of the zone, and plate 3 is the usual large plate.

The ridge is, then, mainly composed of three plates, two on one side of the median line and one on the other.

There is nothing which requires notice with regard to the processes, except that they are expanded above and have a large opening (fig. 46).

But the bases and the ambulacral plates close by are well worthy of study, for the peculiar distribution of the pairs enables the direction of the plates to be distinguished. Benzene also assists, so that the relation of the suture between the process and the ridge, and its continuation between the ambulacrum and the interradium, can be seen, and the connection of this long line of junction with the ambulacral plates (poriferous part) can be made out.

About nine minor plates have their pores on the inner flank of a process; and none of these plates have their poriferous part limited by suture, and the suture between the ridge and the process is remote from the pores. But all succeeding plates have their poriferous zones in contact with the closely placed ambulacro-interradial suture.

VI. The Suborder Clypeastridæ, &c.

Students of the Echinoidea are under great obligations to A. Agassiz for his revision of the genera and his magnificent plates. His descriptions and illustrations of the Clypeastroids are especially excellent, and the drawings and photographs which represent the internal structure of the species are admirable.

The nature of the jaws of the Clypeastroids will be found in most works on the Echinoidea, and all that is necessary to be mentioned here is to follow Agassiz and state that "The mode of articulation of the jaws upon the auricles is entirely distinct in the Clypeastroids and in the Desmosticha; in the Clypeastroids the auricles are disconnected, and when the jaws are in position they completely hide the auricles on which they ride. The muscular system of the jaws of Clypeastroids is reduced to a very feeble band attached to the underside of the pyramids, and extending to the auricles" (Rev. Ech. p. 689). The figures of *Clypeaster subdepressus* (pls. xxx. and xi. *b*), *Echinanthus rosaceus* (pl. xxviii.), *Clypeaster scutiformis* (pl. xiii. *f*), and *Echinodiscus auritus* (pl. xiii. *c*), &c., show the position of the structures, the muscular fibres being omitted.

I have been able to dissect a specimen of *Laganum depressum* which contained the viscera, and I have had the advantage of studying specimens of *Clypeaster* (*Echinanthus*, A. Ag.) *rosaceus* and *Clypeaster humilis* at the British Museum.

It is quite evident that these three species are not formed upon the same type as regards the supports of the jaws. There is an interesting difference which should be of classificatory value; for whilst in both the forms of *Clypeaster* there are two processes supporting a pyramid, in *Laganum* and also in *Echinarachnius*, *Mellita*, and *Echinodiscus* there is but one support to the fifth part of the whole jaw-apparatus.

Unfortunately all the other genera of the suborder have not been at my command; nevertheless, by taking the two forms of

Clypeaster, and *Laganum* as types, the nature of the relics of the disconnected perignathic girdle can be appreciated.

Clypeaster (*Echinanthus*, A. Ag.) *rosaceus*, Linn.—When the abactinal part of the test is removed and the jaws also, the inner surface of the actinal part is seen, and the five ambulacra are noticed to be broad at the peristomial edge and each commences there with a plate on either side of the ambulacral median line. These plates are perforated by a pair of large pores close to the edge, and all the rest is furrowed from side to side and penetrated by a multitude of very small pores (fig. 53). The side sutures of these ambulacral plates (the ambulacro-interradial) are visible at a short distance from the peristomial edge but not up to it. The interradial plates at the peristomial edge are not one half of the breadth of an ambulacrum there. Benzene shows that there is but one plate in the interradium, whilst there are two to an ambulacrum. See also Lovén, Études, pl. xlvii.* Moreover it is seen that one of the processes of the incomplete and very disconnected perignathic (or rather infragnathic in position) girdle has its narrow base limited on one side by the lateral suture of the interradial plate 1, and that this plate is crushed in between the process and the one on the other side (fig. 54). It is evident that the interradial plate no. 1 is narrow and yet long, from the peristomial edge towards the circumference, or outwards; and it is seen that the second pair of ambulacral plates (plates zone *a* 2 and zone *b* 2) are so broad that they extend right into where there should be interradial plates nos. 2, and unite by suture with the second plates of the next ambulacra (fig. 53). The result is that the plate 1 of the interradia is separated circumferentially from the second pair of interradial plates, which are found further outwards. The interradial plate 1 is not covered by a process, but it is between two processes. A process arises from a narrow but long base (fig. 53, *p*), which is in that part of an ambulacral plate where the numerous pores seem to end without coming up to the ambulacro-interradial suture. The spot is the posterior or circumferential and outer corner of the plate, and it is of course far from the median ambulacral line (fig. 53).

Careful amplification shows that the pores are continued in small pairs, placed rather wide apart, upon the flank of the process

* Lovén, 'Études,' gives admirable dissections of the plates of the Clypeastroids. He does not describe the processes, however.

which is towards the ambulacrum (fig. 55). The process is then a part of an ambulacral plate, and as there are two plates in each ambulacrum at the peristomial edge, so there are ten processes as jaw-supports.

Each process is tall, and has a narrow but long base and flanks; the top is small and more or less oval or circular in outline and is smooth. The general direction of a process is upwards and outwards (towards the circumference), and slightly on one side towards the process on the other plate of the ambulacrum. But there is a bending forward towards the peristome in the direction of the upper third of a process, and the slope of it is much sharper in that direction than in the opposite (figs. 54, 55). The processes which look stout, when seen from their sides, are slender and narrow when seen from the front or peristomially, and in that view their divergence over the narrow interradium is evident.

It would thus appear that the processes of *Clypeaster* are the homologues of the processes of the Glyphostomes, and that the function is not the same. In the Clypeastroids the processes are more or less pivots and underneath supports to the jaws, and the duty of the muscle said to be attached is not apparent, but it may be a retractor.

Clypeaster humilis.—The study of a test of this species at the British Museum proved that there is a close resemblance between the processes and those of *Clypeaster rosaceus*.

The interradial plate at the peristome is, however, better defined than in the instance of *C. rosaceus*, and it projects backwards, so that the posterior edge is seen to be thick and curved, and projecting beyond the first ambulacral plates. In front or towards the peristome the interradial plate is low and narrow, and conforms to the general shape of the peristomial margin (fig. 56).

The processes are not connected with this plate, and it has no growth whatever upon it. The processes are similar to those of *C. rosaceus* in shape and in position; they are growths of the ambulacral plate near the peristome, and arise close to the ambulacro-interradial suture. (Probably the first ambulacral plate of an ambulacrum in the *Clypeasters* is a compound one, but I have not proved it to be so.) It appears that the small pairs of pores which are to be seen on the ambulacral side of a process close to its base in *Clypeaster rosaceus* are not visible in *C. humilis*; but I have not been able to examine a sufficient number

of specimens to be able to state that this distinction is invariable.

With regard to the jaws of *Clypeaster*, it will be remembered that each pyramid has two cavities on its inferior surface, and a process fits into each one and supports the jaws. It is not the two processes of the same ambulacrum which fit into the cavities of the same pyramid, but the process of one ambulacrum and the process of the next ambulacrum which is situated just on the other side of the interradium. So far as I can make out, the muscle starts from the front of a process and reaches a pyramid close above the teeth, and it acts with those of the other processes as an opener of the jaws.

Laganum depressum, Lesson.—On dissecting a specimen it is seen that the ambulacra at the actinal surface have a large pore close to the peristomial edge of each first plate, and that the first plates are large and have a median furrow ending in a swelling between the large pores or slightly externally to them. Numerous rows of minute pores start from close to the median line and reach outwards until a radiating series of small tubercles, five or six in number, is reached. These tubercles are within the interradium and are on the interradial side of the ambulacro-interradial suture. A corresponding series of tubercles is on the other side of the single interradial plate no. 1. This plate is single and fits in between two ambulacra, and it is sutured to two interradial plates circumferentially. See also Lovén, 'Études,' plate xlv.

Now on removing the abactinal part of the test and taking off the jaws, it is at once noticed that the arrangement of the girdle is unlike that seen in *Clypeaster*. There are only five projections instead of ten, and each is curved, concavity towards the peristome, from which it is separated by a distance equal to its own height, which is not great however (figs. 50 & 51). The posterior projections are larger than the other three and are more pointed (fig. 52).

Benzene displays, within, the suturing of the plates which were recognized on the surface. The limits of the ambulacral plates are well defined and they are attached to the sides of the interradial plate no. 1. The pores may be seen on the surface of the ambulacra within, and also some stout transverse lines; but it is evident that the projection has not its base within an ambulacral plate. The projections are growths from the upper surface of the first interradial plates, which are single, in each interradium, at the peristome, and they are therefore homologues of "ridges."

The peristomial face of the ridges (for such they are) is usually marked by a depression on either side of their median line, and the other face is convex. The tops may be rounded, pointed, or rectangular, and the breadth of a process is greater than the measurement from the peristomial face backwards.

There are no traces of small plates in the ridges.

Probably the depressions just mentioned are the points of attachment of muscular fibres, and it is evident that the motions of the jaws must be as restricted in this species as in the true Clypeasters.

On looking at the photographs of *Echinarachnius parma*, *E. mirabilis*, *Mellita testudinata*, and both *Echinodiscus auritus* and *E. biforis* in the 'Revision of the Echini,' by A. Agassiz, it is perfectly evident, after the study of the *Laganum*, that they all have the projections single and one in each interradium, and that they are all homologues of the perignathic ridges of the regular Echinoidea.

VII. Conclusions.

As the structures which give attachment to the muscles which protrude and retract the jaws of the Echinoidea, and which are integral and not additional parts of the test surrounding the peristome within, are not homologous in Cidaridæ, Echinidæ, Clypeastridæ, and Laganidæ, it is impossible to retain the old term of "auricles." As the structures form a perfect girdle around the jaws in Discoidea, and more or less disconnected parts of a girdle in other forms, the term "perignathic girdle" is advisable. The girdle consists of "processes" usually united above, but sometimes, and mostly in young forms, disconnected, and of "ridges" which connect the "processes" on the side remote from the ambulacra.

In the Cidaridæ the muscular attachments are all on perignathic and usually disconnected "ridges," which are modifications of the peristomial interradial plates. The ridge is made up of two plates in one interradial zone (plates 1 and 2), and of one plate (1) in the other, there being a median line. The plates of the ridge are the upward growths of the plates just numbered, and which carry tubercles at the peristomial margin actinally. The "ridges" may overhang so much as to join and arch over the ambulacra, as in the specimen of *Phyllacanthus*.

The Cidaridæ have no "processes."

In the Temnopleuridæ the retractor muscles are attached to "processes," one on each side of an ambulacrum; and they join above in an arched form, and the ambulacrum forms the floor of the arched space.

The processes are growths of the *poriferous portions of the ambulacral plates near the peristome*; and the base of a "process" is united by suture with the "ridge" on the interradium, the line of direction of the suture being along the ambulacral side of a groove on the inner or peristomial face of the ridge which leads to the branchial "cut."

The protractor muscles and the ligament of the radiales are attached to the "ridges." Each ridge has a thin upper edge and is made up of a *single plate* comprising the whole of the free edge; and this is followed in one interradial zone by a low and a moderate-sized plate, and in the other zone by two plates, the first of which is larger than the corresponding plate of the opposite zone.

There is no median line of suture on the ridge; and it is evident that this structure is not made on the same lines as the "ridge" of Cidaridæ.

In *Echinus*, when 5 millim. in diameter, the processes are mere nodules, and each is situated *on the inner surface of the first ambulacral plate and between the first pair of pores and the interradial suture*. It is therefore ambulacral, and is not homologous with the projections noticed by J. Müller on the interporiferous zones of *Cidaris*. With growth, the poriferous zones of the first six or seven plates become implicated in the mass of a process.

The "ridge" consists in the young and old forms of a single plate at the edge, and thus it differs from the ridge of *Cidaris*, which is made up of two plates in one zone, and one in the other. In *Psammechinus* more ambulacral plates enter into the structure of a process than in *Echinus*; and on fracturing a process moderately high up, canals are seen continuous with pores.

The "processes" of the Echinometradæ and Diadematidæ are on the same plan as those of *Echinus*, and the "ridges" differ materially.

The ridges are wide and low, and there is no single plate at the edge as in *Echinus* and the Temnopleurids, but two or more plates. There is in one zone a plate 1, and in the other a plate 1 and part of a plate 2; or, a first plate extends beyond the median

line, and crushes up a small first plate in the other zone. These plates are followed in their respective zones by the plates noticed in the Echinidæ and Temnopleuridæ. It is evident that the single plate of *Echinus* is composed of fused first plates and probably of the low second plate of one zone; so that if the ridge-plates of *Cidaris* were united without any relics of sutures, the solitary plate of the ridge of the Echinidæ and Temnopleuridæ would be exemplified.

The ridges of the Glyphostomes are the homologues of the so-called auricles of the Cidaridæ; but their "processes," which are not in existence in *Cidaris*, give attachment to important retractor muscles which are not much required in this last genus.

In the Clypeastridæ there are disconnected growths which carry the jaws and have slight muscular attachments. In *Clypeaster* there are ten processes, and each one arises *from an ambulacral plate* (or plates), and one process leans somewhat towards the other of its pair over the ambulacrum. There are no interradial structures like ridges. The processes are the homologues of those of the regular Glyphostomes.

In *Laganum* there are five growths, and each arises from a single *first interradial plate*; so they are "ridges," and the homologues of those interradial structures of the Regular Echinoidea.

The Clypeastridæ may be divided into two groups, on account of the presence of processes in one, and of the homologues of ridges in the other. The relation of the single interradial plate at the peristome of many edentulous (or presumedly so) Regular Echinoidea to the single plate of the edge of the ridge in *Echinus* is evident; and this is the result of junction of the two plates 1 with or without the addition of plate 2 of one zone. The distinction between the Cidaridæ and the Glyphostomata is well defined by the perignathic girdles.

DESCRIPTION OF THE PLATES.

All the figures in both Plates are more or less magnified.

Plate XXX.

Fig. 1. *Dorocidaris papillata*, Leske. Interradial ridge and the peristomial face of the first ambulacral plates. Part of a ridge beyond an ambulacrum.

Fig. 2. The ridge of interradium 5, seen from above. The arrow points to

the peristome, and the curved dark line is the free upper edge of the ridge. Zone "*a*" has one plate and "*b*" has two plates in the ridge.

Fig. 3. A diagram of the side view of the ridge; the oblique line of suture "*a*" is between the two ridge-plates of zone "*b*," or rather between plates 1 & 2 of that zone. The first plate carries a small tubercle. The horizontal dotted line is the upper limit of the ambulacral sutural face.

Fig. 4. View of the ridge from behind. Zone "*b*" has two plates; *a** is the level of the lower part of the ridge.

Fig. 5. Interradial ridge of the girdle of *Phyllacanthus imperialis*, Lmk.

Fig. 6. Another form, showing ambulacral plates also.

Fig. 7. Showing arching of ridges over an ambulacrum, and junction in one instance.

Fig. 8. *Goniocidaris geranioides*. A ridge and the peristomial end of an ambulacrum; part of a second ridge.

Fig. 9. *Salmacis bicolor*, Agass. The processes forming an arch, the ridge joined to the processes by a suture "*s*;" "*β*" the groove of one side of a ridge leading to a branchial cut. The grooves and pores are shown at the peristomial edge of the ambulacrum and in relation to the processes.

Fig. 10. Side view of ridge (diagram); the connection of a tubercle with the plate is shown.

Fig. 11. Back view of the interradium, its plates and ridge, and of more or less complete processes of the girdle. There is no median suture to the ridge-plate which reaches the free edge, and the base of the ridge is seen to be formed by two plates, by nearly the whole of a low plate in zone "*a*," and a part of a large plate in zone "*b*." The pores and their relation to the suture between the process and the ridge are figured.

Fig. 12. Oblique view of a ridge separated from the adjoining process of the ambulacrum (diagram); the sutural face is covered with minute sockets, and there are traces of a suture which indicate that the low plate is really not plate 2, but that the ridge originally consisted of more than one plate towards its free edge. There is no median suture visible. The figures refer to plates, and the letters to zones of the interradium.

Fig. 13. The sutural face of the process which corresponds to the ridge fig. 12. The surface is covered with knobs and the relics of three plates. The part above the sutural face is the side of the process towards the top.

Fig. 14. Side view of the base of a process from the median ambulacral suture. Plates 5 and 6 have their sutures passing from the median line to the line of ambulacro-interradial suture, but the other plates have not.

Fig. 15. *Microcyphus zigzag*, Agass. The peristomial face of a ridge, showing the tuberosities; there is no visible median suture.

Fig. 16. *Echinus norvegicus*, Düb. & Koren. A pair of processes and a ridge.

Fig. 17. A process cut short, the ambulacral median line is indicated, and on the other side of the pairs of pores is the more or less curved ambulacro-interradial sutural line, which is not reached by the plates close to the base of the process.

Fig. 18. View of a ridge from behind; a^* is the line of base-level of the ridge.
Fig. 19. The processes forming an arch in a small specimen.
Fig. 20. Processes of a smaller specimen, not yet joined and low.
Fig. 21. Processes in a very small specimen; they are mere knobs situated on the poriferous zones of the ambulacra.
Fig. 22. Side view of a ridge, showing the presence of two plates.
Fig. 23. The view of the first three plates of one zone of the ambulacrum of the specimen figured in fig. 21, seen from within the test; the ovoid base of the process is indicated "*p*;" the median line of the ambulacrum is where the figures are placed, and the interradium is marked "*in.*'
Fig. 24. The ridge of an interradium of a large specimen; "a^*" is the line where the ridge begins to rise from the upper surface of the interradium.
Fig. 25. *Psammechinus miliaris.* A ridge seen obliquely and two processes of an ambulacrum forming an arch.
Fig. 26. Processes not joined above; see the line of suture between them and the ridge on one side.
Fig. 27. A ridge, peristomial face.
Fig. 28. A ridge from behind and part of the interradium; a^* is the line above which the ridge rises from the interradial level.
Fig. 29. Side view of a ridge, showing sutural lines.
Fig. 30. Back view of the base of a process, showing the pairs of pores and those which are in plates sutured to the ambulacro-interradial suture.
Fig. 31. A broken process, showing tentacular canals within.

Plate XXXI.

Fig. 32. *Strongylocentrotus lividus*, Lmk., sp. View of the back of a ridge: the numbers refer to plates and the letters to zones of the interradium. The line a^* is that of the level of the base of the ridge, and a^{**} refers to the level of a base. See fig. 42.
Fig. 33. A ridge from behind, showing the presence of two no. 1 plates at the free edge, instead of only one as in fig. 32.
Fig. 34. A ridge, back view, showing almost complete exclusion of one of the first plates at the edge.
Fig. 35. *Echinometra lucunter*, Leske. A typical arrangement of the plates of a ridge, seen from behind.
Fig. 36. Outline of the capped processes of *Echinometra lucunter.*
Fig. 37. *Echinometra subangularis*, Leske, sp. The capped processes.
Fig. 38. *Strongylocentrotus lividus.* A process seen from behind and sideways, showing the large and small pores, and that the plates of pairs 4 and 5 reach the ambulacro-interradial suture.
Fig. 39. The ridge has been separated at the suture from the side of a process, and "γ" is the suture-face on the side of the process; "x" is a line which marks the base of the process; and the numerals 4 and 5 are placed over the tops of the interradial ends of the corresponding ambulacral plates.
Fig. 40. A front or peristomial view of a process, showing the limits of plates forming the base of it; "x" is the line of limitation.

Fig. 41. *Diadema setosum*, Gray. A ridge from behind.

Fig. 42. A ridge of another specimen, from behind.

Fig. 43. A ridge showing the encroaching plates 2 on the edge.

Fig. 44. The suture-face at the side of a ridge between it and a process; three plates are seen at their edges in the ridge, and thus the plate at the actinal surface next to the peristome, and which would be counted as plate 1, is really plate 3. It is marked "*a*," and the lamellar condition of the suturing is very distinct.

Fig. 45. The suture-face, showing the lamellar condition and the great projection of the peristomial part or face of the ridge.

Fig. 46. Outline of the processes and wide arch.

Fig. 47. Side view of junction of a ridge and process.

Fig. 48. *Echinothrix Desori*, Peters. The ridge of an interradium from behind, the line "*a**" denotes the commencement of the rise of the ridge.

The black markings are in the positions of the usual depressions on the plates.

Fig. 49. A magnified view of the sutures at the median line of the figure 43.

Fig. 50. *Laganum depressum*, Lesson. View of part of the test, lower part, seen from within at the edge of the peristome. "*A*" is part of an ambulacrum, and "*in*" is the whole of the first interradial plate on which is the small upward projecting homologue of a ridge. The plate is single, and is succeeded by plates 2 of both zones.

Fig. 51. Side view of interradial plate and ridge.

Fig. 52. One of the posterior projections (ridges).

Fig. 53. *Clypeaster* (*Echinanthus*, A. Ag.) *rosaceus*, Linn. Internal view of the actinal part of the test at the peristome. "*A*" is part of the ambulacrum; "*in*" is the single interradial plate; "*p*" is the base of a process.

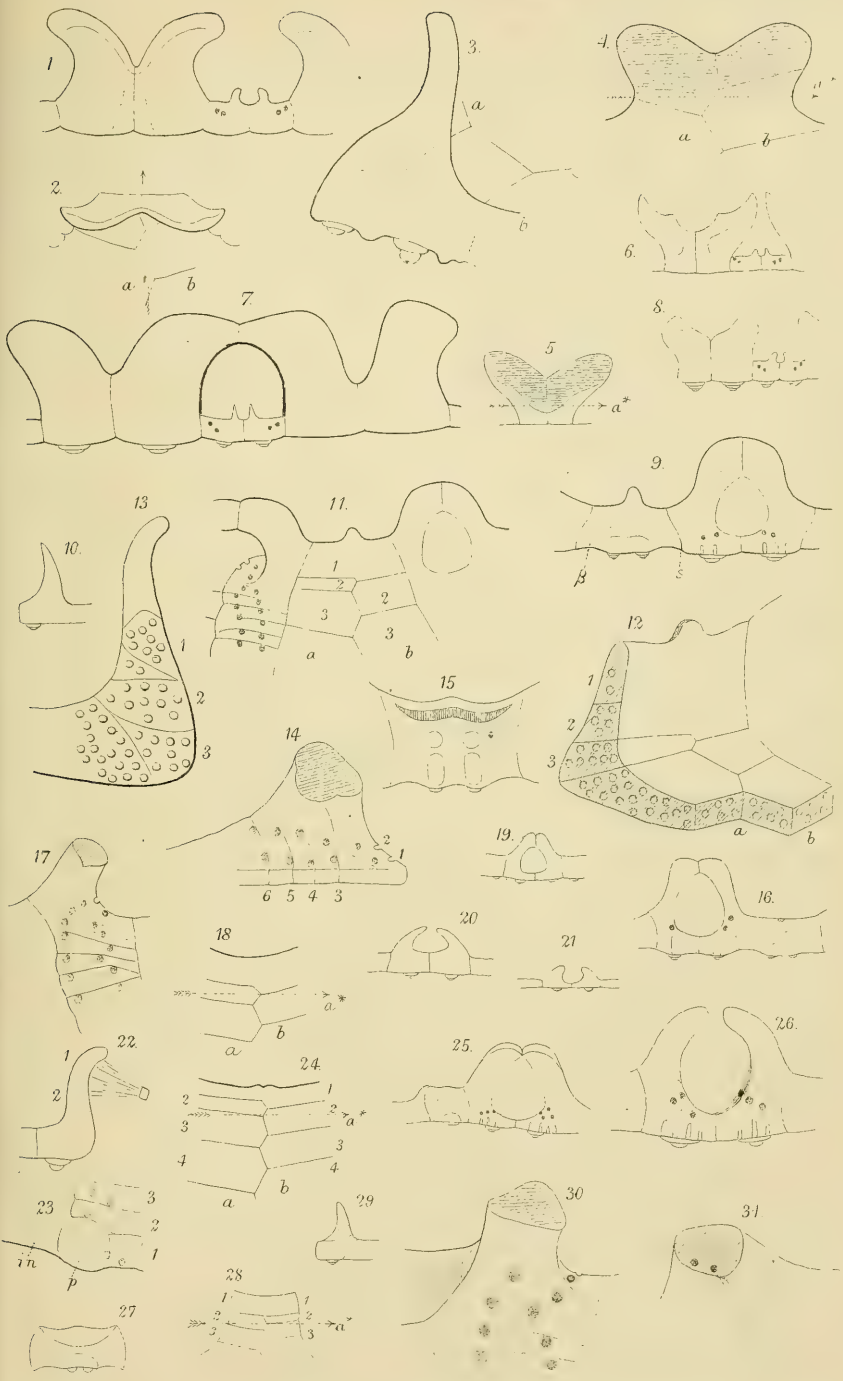
Fig. 54. Processes of neighbouring ambulacra with their bases separated by a narrow interradial plate.

Fig. 55. A view of a process of an ambulacrum, seen from the median ambulacral line outwards. The small pairs of pores are on the flank of the process.

Fig. 56. *Clypeaster humilis*, A. Agass. The actinal part of a test seen from within and at the peristome. The central single plate is the interradial, and it is narrowest at the peristome "*in*." The ambulacra on either side are partly shown, and the bases of the processes of two neighbouring ambulacra are marked "*p*."

Fig. 57. An oblique view of the same surface and specimen, showing the processes and the intervening interradial plate.

Fig. 58. View from behind; "*in*" is the posterior edge of the stout interradial plate, and the plates on either side are ambulacral.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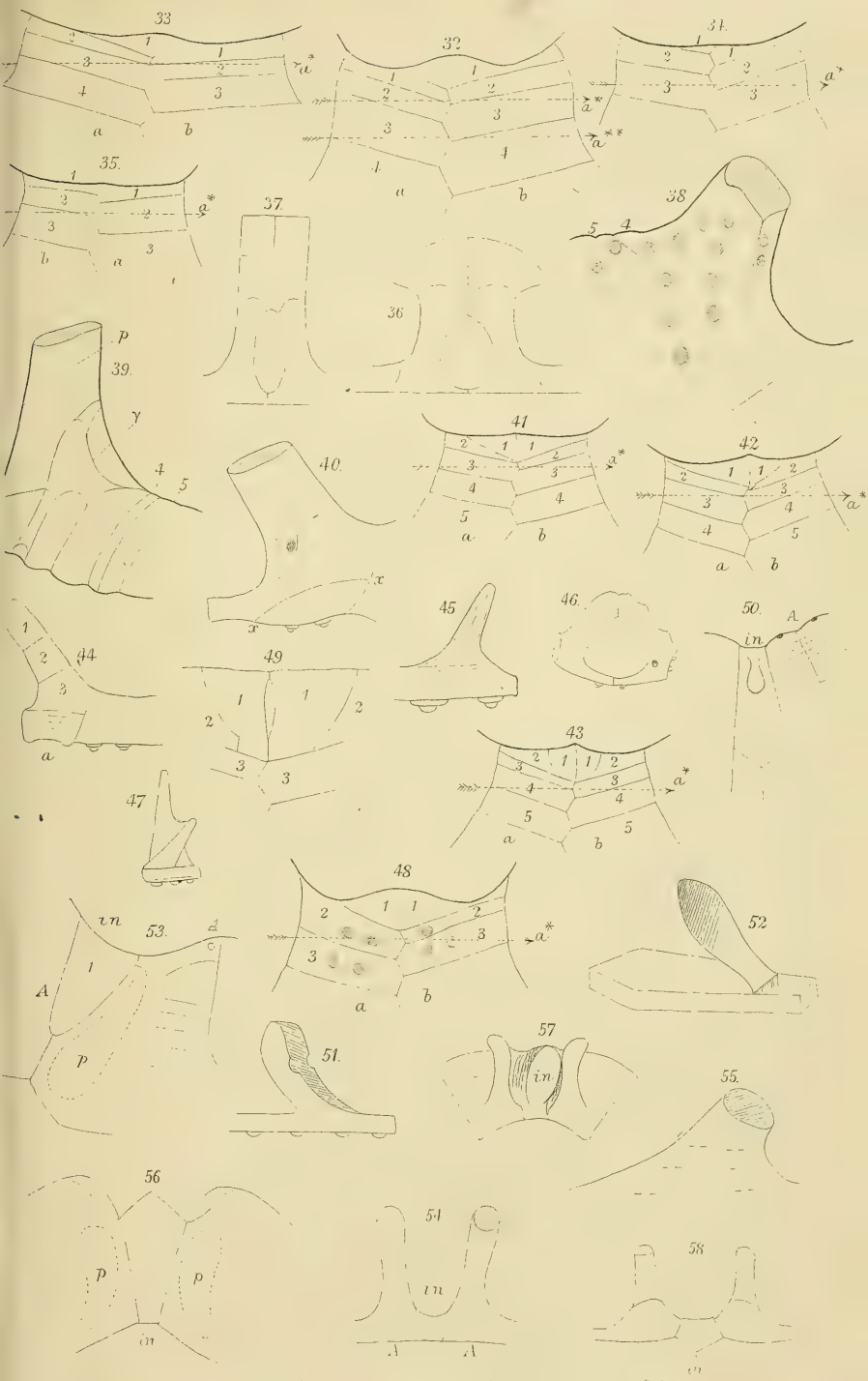

STRUCTURES OF PERIGNATHIC GIRDLE

Carter sc.